Overview of Accelerator Physics Integration

Valeri Lebedev
FNAL

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Talk outline

1. Beam physics integration: Aims and Objectives
2. Optics
3. Beam physics and instrumentation
4. Basic accelerator physics problems

1. Beam physics integration: Aims and Objectives

- Three major objectives:
  - (1) Building the model, (2) Machine studies and (3) General beam physics coordination
- Physics model of the entire complex
  - Optics
    - Software for optics design, optics meas. and data analysis
    - Repository of optics files
      - Set of rules and requirements to the files
  - Basic accelerator physics problems
    - The work is mainly performed in system departments
    - Certain coordination and help are required
    - Avoiding the duplication of efforts
  - Instrumentation
    - Instrumentation problems which require deep insight into physics of the device operation

Aims and Objectives (continue)

- Machine Studies
  - Develop and prioritize study plans
  - Monitor the study proposals and write-ups of System departments
  - Enforce an effective use of study time
- Coordination
  - Department to department, and Tevatron to CDF and D0
  - Accelerator physics task forces
  - Prioritization of the accelerator physics issues for the accelerator complex
  - Weekly meetings (together with Jean Slaughter)
    - Run II accelerator physics
    - Beam physics in instrumentation

2. Optics

- **Optics tools and software**
  - Presently, a number of optics codes are used. Each of them has its own drawbacks.
  - We are building new optics code which should address our present and future needs
    - Main features
      - Integrated GUI
      - MAD-8 extension for lattice description
      - Runable in Linux and Windows
    - We have all the peaces. Need to glue them together
      - Schedule

        First public use - this summer.

        Total duration of active phase - < 2 years
- **Optics files repository**
  - Will address long-standing problem of saving and exchange of optics info/files. It is in line with effort to improve magnet and survey databases

♦ Optics measurements

- Differential optics measurements
  - Present measurements are optimized to minimize study time. It fits well for transfer line measurements.
    - Data taking is fully atomized
    - Analysis half-manual requires significant time
      - ~2 hours for 8 GeV Accumulator-to-MI pbar transport
      - ~2 days for Tevatron but better accuracy is required
  - Analysis can be improved if data is sufficiently redundant
    - In collaboration with ANL we build new software
    - Data acquisition is under testing
    - Computational engine tests with real machine data are expected within month
    - First, the project is aimed for Tevatron and Debuncher where "the optics perfection" is the must. Other machines will follow later.

- **Optics measurements (continue)**
  - Turn-by turn
    - Greatest advantage that it allows one to perform measurements much faster
      - Significant advantage in the case when study time is limited
    - Present
      - Used at limited number of machines which have reliable measurements: MI & Recycler
      - Coupling and signal decoherence due to chromaticity are ignored
    - Solving Tevatron problems requires expansion of the scope
      - Coupling
      - Non-linearities
      - Effects of signal decoherence due to chromaticity/tune spread need to be alleviated

♦ Optics status/priorities

- Tevatron
  - Low beta optics and helix need to be corrected
  - Measurements of Tevatron nonlinearities is highly desirable
- Electron cooling
  - The beam is recirculateing but better understanding of machine optics is required
  - Optics redesign for MI-30 is under way
    - Means of optics correction need to be addressed
- Debuncher and AP-2 line
  - Detailed knowledge of optics and orbits is required to maximize the machine admittance
  - Chromatic correction for AP2 line
- Optics correction in the booster and the linac-booster line are under study

3.Beam physics and instrumentation

- Many instrumentation problems require deep insight into underlying physics
- We have a weekly meeting to facilitate an interaction of the instrumentation department with physicists
  - Problems to be addressed for the entire accelerator complex
    - Transverse and longitudinal emittance measurements
    - Tune measurements
    - Intensities and efficiencies

Beam physics and instrumentation (continue)

- A few problems where the help/coordination has been highly valuable
  - Tevatron BPM project
    - Suppression of head-tail motion effects on turn-by-turn operation
  - BLT measurements
    - Algorithms for signal decomposition and many more
  - Longitudinal emittance measurements through entire complex
    - Obtaining quantitative emittance information for the beam in strongly non-linear longitudinal potential
  - Sync-light operation
    - Radiation from the magnet body
  - Bunch-by-bunch tune measurements in Tevatron
    - Significant efforts are required to reach desirable accuracy

4. Basic accelerator physics problems

- **Recycler**
  - Analysis of pbar deceleration due to collisions with residual gas atoms was helpful in building strategy for vacuum improvements
  - Careful analysis of Recycler operation with stochastic cooling was performed
    - It was found that putting Recycler into operation with stochastic cooling only can yield only modest improvements for stacking.
      - Experimental studies carried out now will yield more quantitative answer.
      - Updating the collider scenario with stochastic cooling alone will follow
    - Achieving successful operation of electron cooling has one of the highest priorities for the Run II success
  - Obtaining required small longitudinal emittance with electron cooling is based on reduced IBS in the case of equal longitudinal and transverse temperatures
    - Experimental studies of mechanisms responsible for the beam heating is under way in Recycler

- **Recycler (continue)**
  - There is considerable progress in measurements of long. emittance in barrier buckets
  - Transverse instabilities
    - Broad-band transverse damper: setting requirements and design
- **Electron cooling**
  - Recently we found out that single IBS (Touschek effect) in the electron beam leads to particle loss from recirculation
  - Optics has been redesigned to alleviate it.
    - Calculations yield lass reduction by almost factor ~6
    - Further optics improvements are under way.
  - Procedures and software for optics correction need to be worked out
  - Absolute energy calibration for Recycler and Electron Cooler needs further work

- **Antiproton source**
  - Optics
    - Optics design
      - Suppression of chromatic effects in AP2 line
      - Optics correction for AP2 - P1 8 GeV and 120 GeV to the target to accommodate quad tilts in P1 line
    - Optics measurements and optics matching
      - Debuncher
      - D-to-A line

        Has not been measured with present settings. Both empirical tune-up with reverse protons and dif. orbit data needs to be acuired
      - ·Accumulator

        Chromaticity in Accumulator (operationally has not been an issue, but does have the wrong sign at the core for stability in the vertical plane. Is there a fix?)

Antiproton source (continue)

- Fast pbar transfers
  - Power supply regulation for AP1 (running AP1 at 8 GeV off of 120 GeV supplies with ramp cards)
  - Pbar injection damper in MI: specs on kick and voltage required to minimize emittance growth
- 8 GeV energy definition
  - Power supply settings for AP2, Debuncher, D-to-A, Accumulator, AP3, AP1, P2, P1 with redefined energy (from Recycler)
- Quad BPM in Accumulator
- Stochastic cooling
  - Understanding of limitations of the stack-tail system and recommendation for improvements

- **Booster**
  - Optics
    - Understand and improve the 400 MeV beam transfer line
    - Understand and improve booster lattice
  - Optimize RF capture and early acceleration ramps
  - Commissioning the collimation system
  - Orbit control with ramped correctors
  - Dampers
  - Transition crossing

- **Main injector**
  - Slip stacking
    - Beam loading compensation and instabilities
      - Feedforward
      - Longitudinal damper
  - Transition crossing
  - Single bunch instabilities
  - Slow extraction optimization

- **Tevatron**
  - Tevatron optics
    - Linear optics correction
      - Done at Injection and Flat top
      - Low Beta optics and helix are in a process of correction
    - Building non-linear Tevatron model
      - Presently there is large difference between model predictions and observations
    - Study of sources of orbit drifts
      - Sources of data: BPMs, water gauges
    - Feeddown correction of coupling and dif. chromaticities
      - Additional octupole and sextupole circuits were installed at the 2003 shutdown
    - Further optimization of helices and increase of separation

Tevatron (continue)

- Model for the luminosity evolution
  - Measurements of bunch-by-bunch tune shifts and chromaticities and comparison with computations
  - Simulation of beam-beam effects in the presence of diffusion
  - Experimental study of longitudinal and transverse dynamics driven by IBS and beam-beam effects
- Instabilities
  - Transverse instabilities
    - ^ impedance reduced, beam is stable for pos. chromaticities
    - Introducing tune shift by octupoles should improve stability
  - Longitudinal instabilities
    - Longitudinal impedance measurements
    - What is the shortest bunch which Tevatron can support

Conclusions

- We are making steady progress with luminosity growth and with understanding of Tevatron complex operation
- There is still large potential for further growth of both peak and integrated luminosities
- The progress has been and will be supported by both improvements in operations and better understanding of underlying physics
- Good coordination of beam physics efforts is essential for the Run II success